Fire in Folded Rocks

GEOLOGY OF HOT SPRINGS NATIONAL PARK

HOT SPRINGS NATIONAL PARK

FIRE IN FOLDED ROCKS

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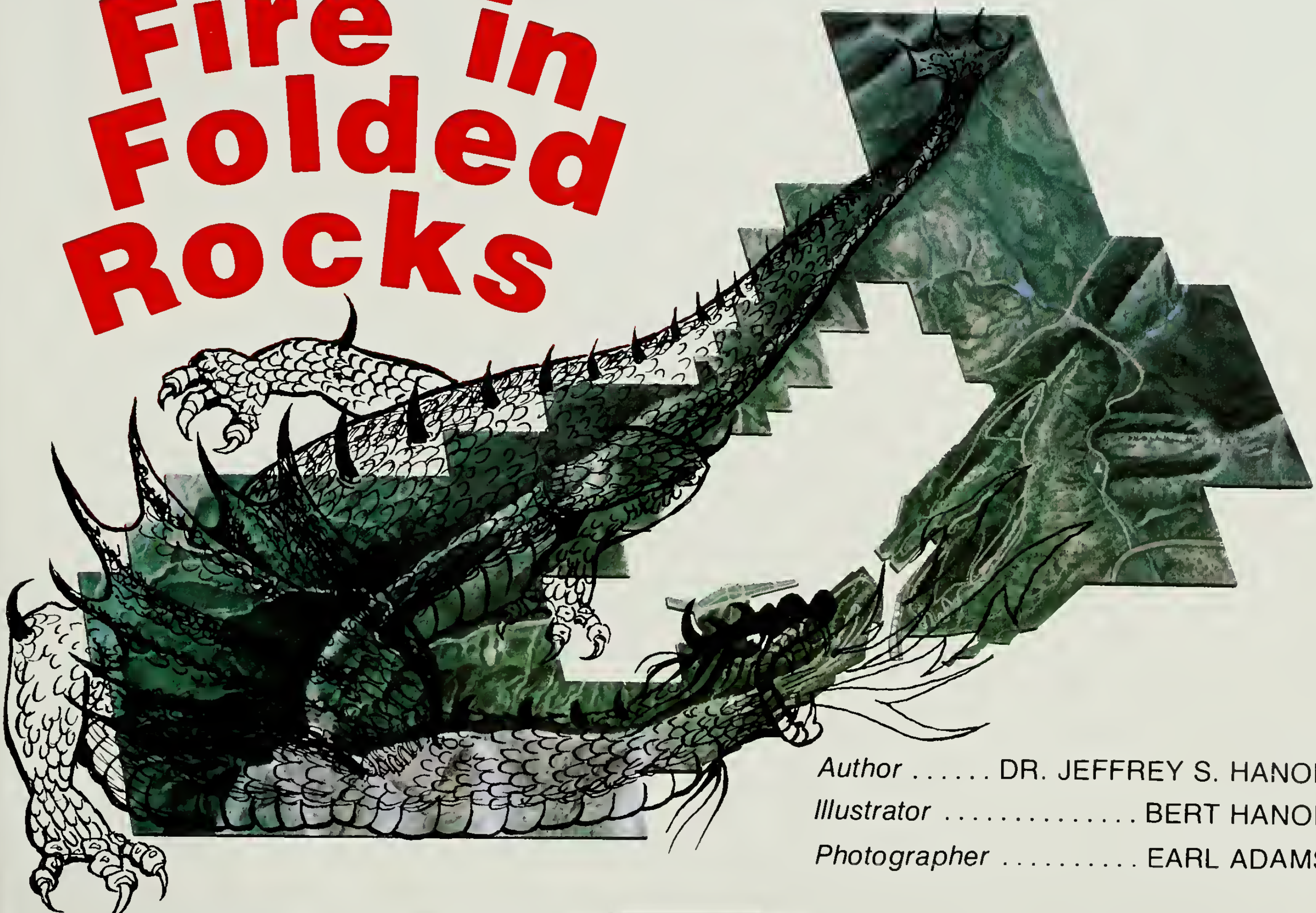

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UNFOLDING

TO BEGIN WITH

Today's visitor to Hot Springs National Park is likely to ask many of the same questions that the first Indian visitors to the area asked thousands of years ago. Where do the spring waters come from? Why are they hot? What incredible forces have folded and bent the rocks exposed in the surrounding mountain ridges?

Ancient Indian legend provided an explanation that was both elegant and reasonable for its time:

The Great Spirit favored every rock, tree, and bush in these quiet mountains and regarded the place as an important resting spot. But on this placid scene came Mogmothon, a fierce dragon who created tremendous thunderstorms and devastated the land with earthquakes. Poxes and hunger befell the people. A council of all of the Indian Nations assembled and pleaded with the Great Spirit to restore this wonderful place and return happiness to the people.

Mogmothon exhibited such power and cunning that the Great Spirit had to call on all of the forces of the heavenly bodies to subdue him. Even when hurled into a cavern and covered with a mountain, the beast occasionally shook the earth and caused mild thunderstorms. As a reminder to the people of his power to create good, the Great Spirit rent the earth, bringing forth pure, healing water. He asked in return that his favorite place be forever neutral ground, a place to partake of life and health.

We have no evidence today that Mogmothon or one of his descendants is living beneath the city of Hot Springs. However, the explanation that geologists have for the origin of the springs and mountains is as equally exciting and colorful as the old Indian legend. In the sinuous hills of the Park an ancient story is written of the destruction of an ocean basin and the collision of continents. The hot springs themselves record the final phase of a four thousand year journey of rainwater through the heated depths of the earth. We will investigate these stories further in the pages which follow.

Ceremonial bathing – a torrid steam bath followed by a plunge in cold water offered a stimulating spiritual experience.

EXPLORATION AND DEVELOPMENT

Archeological evidence indicates that Indians inhabited the Hot Springs area for many thousands of years. They gathered to work ancient stone quarries along the rocky ridges and to bathe in the warm, healing waters. The Caddos believed that their ancestral tribe had been created in the waters of the hot springs.

According to local tradition, the first Europeans to visit the area were Hernando DeSoto and his men in the Expedition of 1541. A chapter in one of the old Spanish narratives of this expedition is entitled, *"Hot rivers and salt made from sand."* The text of the chapter, however, has been lost, and it is not known whether the conquistadores actually visited the hot springs, which are fresh water, or one of the several warm, salty seeps that are known elsewhere in the region.

The French followed the Spanish into Arkansas. Although they left no written record, these early trappers and hunters were obviously aware of the presence of the hot springs. Many of the features in the Park area, including Hot Springs Creek (Bayou des Sources Chaudes) and Gulpha Creek (Fourche à Calfat) originally had French names. The springs began to acquire a reputation for medicinal qualities. A few adventurous, early visitors traveled great distances overland in hopes of being cured of afflictions such as fever and paralytic disorders.

In 1803, the United States purchased the Louisiana

Territory from France. President Thomas Jefferson naturally was anxious to discover what had been bought and initiated several expeditions to explore these new lands west of the Mississippi. William Dunbar, a planter and naturalist from Natchez, and Dr. George Hunter, a chemist from Philadelphia, were commissioned to lead an expedition up the Ouachita River to explore the hot springs.

The party of 15 left Natchez on August 15, 1804, and worked its way down the Mississippi and up the Red and Black rivers to the lower reaches of the Ouachita. They slowly navigated up the Ouachita, making an accurate survey of the river as they traveled northward. The two explorers took detailed notes on plant life, salt and mineral deposits, general geography, and their encounters with Indian culture. In early December, they unloaded their boats at a point where Gulpha Creek enters the Ouachita. Here, they began the nine-mile (14 kilometer) overland trek to the valley of the hot springs. The narrow valley was deserted, but the group did find an abandoned cabin which had been constructed by health seekers. The chilled party promptly took up residence to avoid pneumonia. Thus headquartered, they were eager to observe the object of their long journey — the thermal springs.

The springs were an impressive sight. Clouds of water vapor billowed up from numerous spring openings along the bank and on the hillside east of the stream which flowed along the valley floor. A gentle smoke seemed to emerge from lush thickets of brilliant green plants. The hillside was covered by a blanket of calcium carbonate, variously known as travertine or tufa. Hunter would write in his

The Caddo Indians believed as a people they originated in the thermal springs.

Indians and Europeans sought the springs for a variety of reasons.

journal, "The hot water . . . has deposited an immense mass of a porous limestone on the side of this hill . . ." "There is no part of this hill covered with this crust (which is from ten to forty feet thick and extends three or more hundred yards long and about 150 feet high) except where the hot water does or manifestly has issued. All the rest of the mountain above and on each side is composed of hard, flint stones." Many of the springs had built up low cones of tufa. Some of the calcareous material was stained various shades of orange and red by traces of iron oxide.

Featherstonhaugh, a British geologist hired by the U.S. Congress to study the highlands between the Missouri and Red rivers, visited the springs some thirty years later. His account provides us with additional information on how the springs originally appeared: "The travertine . . . sometimes present[s] abrupt vertical faces of from 15 to 25 feet high, and at other times show[s] itself in curtains with stalactitic rods." All of these early scientists were impressed by the luxuriant masses of green moss which grew in the hot waters.

During the three weeks they remained at the springs, Dunbar and Hunter made numerous measurements of the physical and chemical properties of the waters, conducted topographic surveys, and took notes on the flora, fauna, and rock types they observed. They found that the temperature of the various springs ranged from 132 to 150°F (56 to 66°C). Not boiling, but, "so hot as to make it impossible for a person to hold his hand half a minute in it." Hunter performed a series of chemical tests and found that the water was nearly pure and contained a small proportion of carbonic acid, dissolved lime, and traces of iron. His findings have been confirmed many times since by more modern techniques. The two explorers conjectured that the waters are heated "in the bowels of the hill" by chemical reactions involving sulfur, clay, and bitumen. A satisfactory explanation for the source of heat has remained elusive up until recent times.

After their return home, Dunbar and Hunter communicated their findings to President Jefferson. There was great interest in their vivid descriptions of the "Hot Springs of the Washita," and accounts of their discoveries were published in the respected periodicals of the day.

In the decades which followed publication of the report of the Dunbar and Hunter expedition, increasing numbers of visitors traveled to the springs to soak in primitive comfort. Some of the visitors who had recovered their health or just simply liked the country remained in the valley and built cabins to rent to other visitors. A simple hotel was in existence by 1828. On the basis of the widely publicized accounts of Dunbar and Hunter and the increasing number of favorable testimonials by invalids who had bathed in the waters, the U.S. government in 1832 set aside the hot springs and the immediately surrounding area as a federal reservation. Direct federal supervision was not implemented, however, until 1877. In 1921, the area was designated as a National Park.

The first bathing facilities at the hot springs were simply the natural, shallow pools in the bed of Hot Springs Creek. Here, thermal waters from springs in the creek bed and adjacent bank and hillside comingled with the cool waters of the creek. A bather could judiciously select a

portion of the stream characterized by a temperature appropriate to his frame of mind or physical malady.

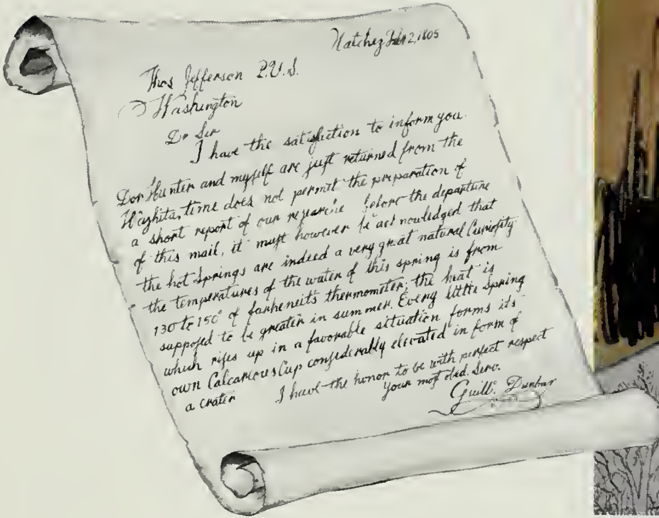
The first bathhouses, which were constructed in the late 1830's, were really little more than brush huts and log cabins placed over excavations cut in the rocks to receive hot water that flowed from the springs. More elaborate bathing facilities soon developed, and a complicated series of wooden troughs was constructed to convey hot water from springs on the hillside to bathhouses located on the valley floor. These bathhouses were built along the east bank of Hot Springs Creek. Some of the tufa covering the hillside was excavated and removed to make room for them. The visitor of that time would cross over Hot Springs Creek via a bridge from the narrow street which ran the length of the valley. The creek, however, had a tendency to flood and was muddy during wet weather, foul during dry.

Much unplanned growth occurred before direct federal supervision was exercised in 1877. Shortly after this event, an engineer from Yellowstone National Park was detailed to make major improvements. The creek was eventually arched over and the space above and on either side filled in, permitting construction of a street 100 feet (30 meters) wide. Diggings, tents, shacks, and rubbish cluttered the area above and between the springs. All squatters were evicted, a few of the springs were encased, and a centralized plumbing system was begun. Individual bathhouses, however, still had ingenious but often unreliable flumes and pipes leading from various springs. Not until comparatively recent times has a unified central collection, cooling, and distribution system been achieved.

Individual springs began to gain a reputation for alleviating specific ills. Some of the names given the springs refer to their chemical properties: Magnesia, Big Iron, and Arsenic. Big Iron deserves its designation for the ocherous crusts and stains that precipitate from its water. Arsenic Spring, on the other hand, contains no detectable traces of that substance. An anomalous pair of cold-water springs were named after adjoining organs of the body: Kidney and Liver. Drinking copious quantities of Kidney had the predictable effect, but the value of Liver remains obscure. These two springs are no longer in existence.

At one time or another, almost any of the open springs could have gone by the designation, "Mud". This name, however, was reserved for the most viscous of the lot. Mud Spring was a favorite among early bathers, who could ease themselves into its tepid ooze without fear of getting parboiled. Minor differences in the composition of the individual spring waters do exist but their overall similarity indicates a common origin. All of these waters are now mixed together, and a single water of the same composition is supplied to each of the bathhouses.

In 1905, Professor B.B. Boltwood of Yale showed that the waters contained a measureable level of radioactivity. This radioactivity is due primarily to the presence of dissolved radon gas, secondarily to radium. These two elements come from decay of tiny traces of uranium and thorium which are scattered throughout the rocks through which the thermal waters flow. Both radon and radium were considered in the past to have curative properties. As a result, collection and distribution equipment was specifically designed to retain the radon gas. Today, we recognize that it is probably not healthful to be exposed to uncontrolled radiation of any kind. The radon gas, however, is initially present in extremely small quantities, and most es-



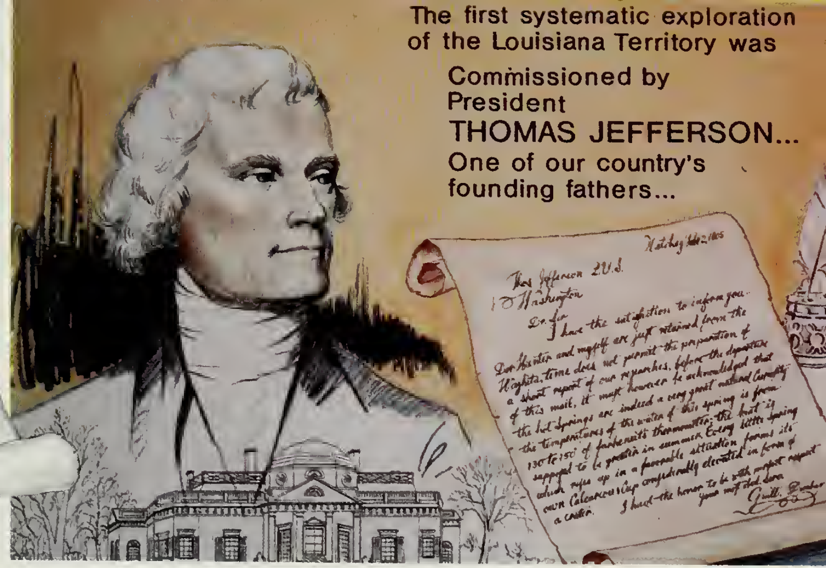
Natchez Feb 2, 1805

Thos Jefferson P.U.S.
Washington

Dr Sir

I have the satisfaction to inform you Dor Hunter and myself are just returned from the Washita, time does not permit the preparation of a short report of our researches before the departure of this mail, it must however be acknowledged that the hot Springs are indeed a very great natural Curiosity the temperatures of the water of this spring is from 130 to 150° of Farheneits thermometer, the heat is supposed to be greater in summer. Every little Spring which rises up in a favorable situation forms its own Calcareous Cup considerably elevated in form of a crater

I have the honor to be with perfect respect
Your most obed. Servt.
Guill. Dunbar



capes into the air space in the storage reservoirs before the hot waters are pumped to the bathhouses. The level of exposure to radiation that results from bathing in these waters appears to be similar to the level that would result from sitting in the sun for the same period of time. A greater exposure may result from drinking the water. Even though water quality standards for public supplies have been considerably tightened in recent years, park water is considered well within safe limits. Other natural waters within the region and throughout the world have similar levels of activity. However, our attitude has changed completely from the days when it was exciting news to hear that Hot Springs waters have activity levels comparable to those of fashionable European spas.

The modifications which have been made to the Valley of the Hot Springs over the years are a natural consequence of public interest in the use of the hot waters for medicinal bathing and of government desire to protect and manage this resource in an equitable manner. Because of the physical changes which have resulted, however, it is difficult for today's visitor to imagine what the springs must have looked like in their original state. All but two of the springs are covered over, and their water now runs through underground pipes rather than filtering down over the hillside. Hot Springs Creek flows through a tunnel beneath Central Avenue. The valley floor has been filled in to make it flatter

and wider. Large areas of tufa have been removed or covered over. Exotic varieties of plants have been introduced into the area.

Still, the visitor who spends a little time in the area can partially reconstruct what the springs must have looked like. As shown by the map, most of the hot springs lie immediately north and northeast of the gates to the Park in the display springs area. A few springs are located to the south. The springs have been walled in and covered over to minimize contamination by surface water. Several of these protective coverings, each marking the position of a spring, are located between De Soto Rock and the Superior Bath House. Others can be seen on the hillside immediately above. Forty-seven individual springs are recognized. This number has varied in the past as old springs have sealed themselves shut by precipitation of calcium carbonate and as new springs have formed when the water chooses a different path through the tufa. Two of the springs are not covered and can be observed at the **display springs site.** Here, the visitor can see the tufa which has precipitated from the water, gauge the rate of flow, and verify Hunter's measurement of temperature. A hot water fountain is nearby, but a more convenient place to taste the water is at the fountain at the Park Visitor Center.

The individual springs vary in the amount of water they discharge. Some are mere seeps. The total amount of water discharged by the hot springs as a group range from 750,000 gallons per day (3.3×10^{-2} m³/s) to about 950,000 gallons per day (4.2×10^{-2} m³/s). Studies by the U.S. Geological Survey show that discharge is highest in winter

The temperature of the spring water averages about 143°F (61°C). There is some seasonal variation due to annual variations in surface ground temperatures and the inevitable mixing of spring water with seepage from rainfall. Maximum water temperatures have declined about 5°F (3°C) since records have been kept. Dissolved silica content, which is also a measure of maximum water temperature, has also declined slightly. Perhaps the heating system at depth is cooling gradually, or perhaps there has been greater mixing with surface waters.

One of the most outstanding sights in the Valley of the Hot Springs was the massive blanket of calcareous tufa on the side of Hot Springs Mountain. Vestiges of the tufa can still be seen in several places in the Park. It is exposed at the display springs and forms the cliff in back of Bathhouse Row. De Soto Rock, across from the Arlington Hotel, is a large block of tufa that has tumbled down from the steep cliff just to the east. The boulder has rolled onto its side. The front face, which holds the plaque commemorating the De Soto Legend, is really the bottom of the tufa layer. The angular blocks of sandstone which stud this surface are part of an old soil layer on Hot Springs Mountain. When the thermal activity began thousands of years ago, these blocks were cemented together and eventually buried by a thick layer of carbonate. The side of De Soto Rock opposite the plaque is the top of the tufa layer. It is very porous and has

Hunter & Dunbar found the springs little disturbed from thousands of years of use.

numerous openings and channelways through which thermal water once flowed.

Another interesting exposure of tufa is located on the hillside above the Promenade near the north gates to the Rehabilitation Center. This is far above present hot spring activity. Here lies a broad dome of porous calcium carbonate about three feet (one meter) thick where it is cut by the old carriage roadway. The deposit overlies from 2 to 6 inches (5 to 15 cm) of a black silty material, probably an old soil layer. This dome may represent some of the oldest tufa in the Park. We do know that the springs which deposited it were extinct by the time of Dunbar and Hunter's visit in 1804.

The tufa cliffs are no longer forming because most of the hot water is now diverted. Nature cannot be completely controlled, however, and some calcium carbonate now precipitates out in the pipes and reservoirs of the Park's hot water collecting system.

IN HOT WATER

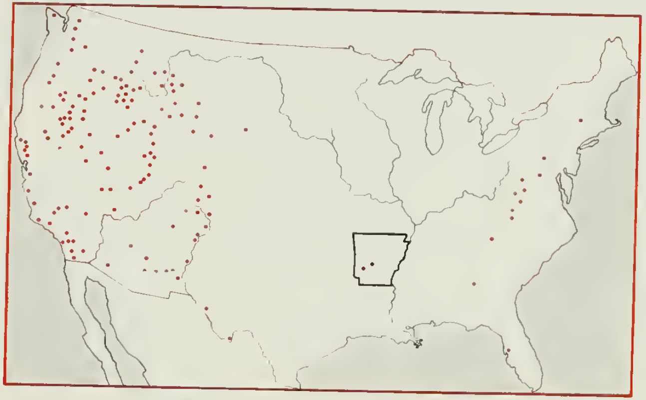
The origin of the hot springs has been debated since the time of Dunbar and Hunter's visit in 1804. Most explanations have focused on one of two alternatives: Do the spring waters rise from hot magmas at depth? Or are they originally rainwater which has percolated down deep into the earth's crust, there to be heated by some unknown process? Over the last several decades, sensitive chemical techniques have been developed that provide some of the answers to these questions.

The water of the hot springs, like all water, is made up of the elements hydrogen and oxygen in the form, H_2O. Each of these two elements have closely similar forms known as **isotopes.** Geochemists at the United States Geological Survey have measured with great accuracy the abundance of the isotopes of hydrogen and oxygen in the spring waters. By comparing these results with results obtained by analyzing large numbers of different kinds of waters from all over the world, these scientists conclude that this water now flowing from the hot springs is **not** water given off by cooling magmas at depth. It is, in fact, **rainwater.** Furthermore, analyses of carbon-14, another

isotope present in the water, indicate that this rainwater originally fell in the Hot Springs area some four thousand years ago.

How does four thousand year old rainwater become heated to an average temperature of 143°F (61°C)? The answer to this is still speculative. We do know that the temperature of the earth's crust increases with depth. The average increase world-wide is on the order of 3 or 5°F (2 or 3°C) for every additional 300 feet (100 meters) depth and is due to the release of heat by the natural radioactive decay of potassium, uranium, and thorium in the crust. We can heat rainwater simply by letting it percolate slowly downward to the desired depth and temperature. If we can then make this heated water rise back up to the surface rapidly, so that it doesn't have a chance to cool, we will make a hot spring.

What are the details of this process in the Park area? Best evidence indicates that most of the rain which is transformed into thermal water is collected in the broad valley in the northern part of the city of Hot Springs. Whittington Avenue, Park Avenue, and Highway 7 gently curve their way northeastward along the floor of this valley. This area is underlain by the Bigfork Chert, a hard, brittle rock that is extensively fractured and broken as a result of mountain-building activity in the past. Water flows readily through the numerous cracks and pores which penetrate this rock, and there are numerous cold-water springs in the valley. Some of the rainwater is probably collected along the ridges of Arkansas Novaculite which flank the valley.

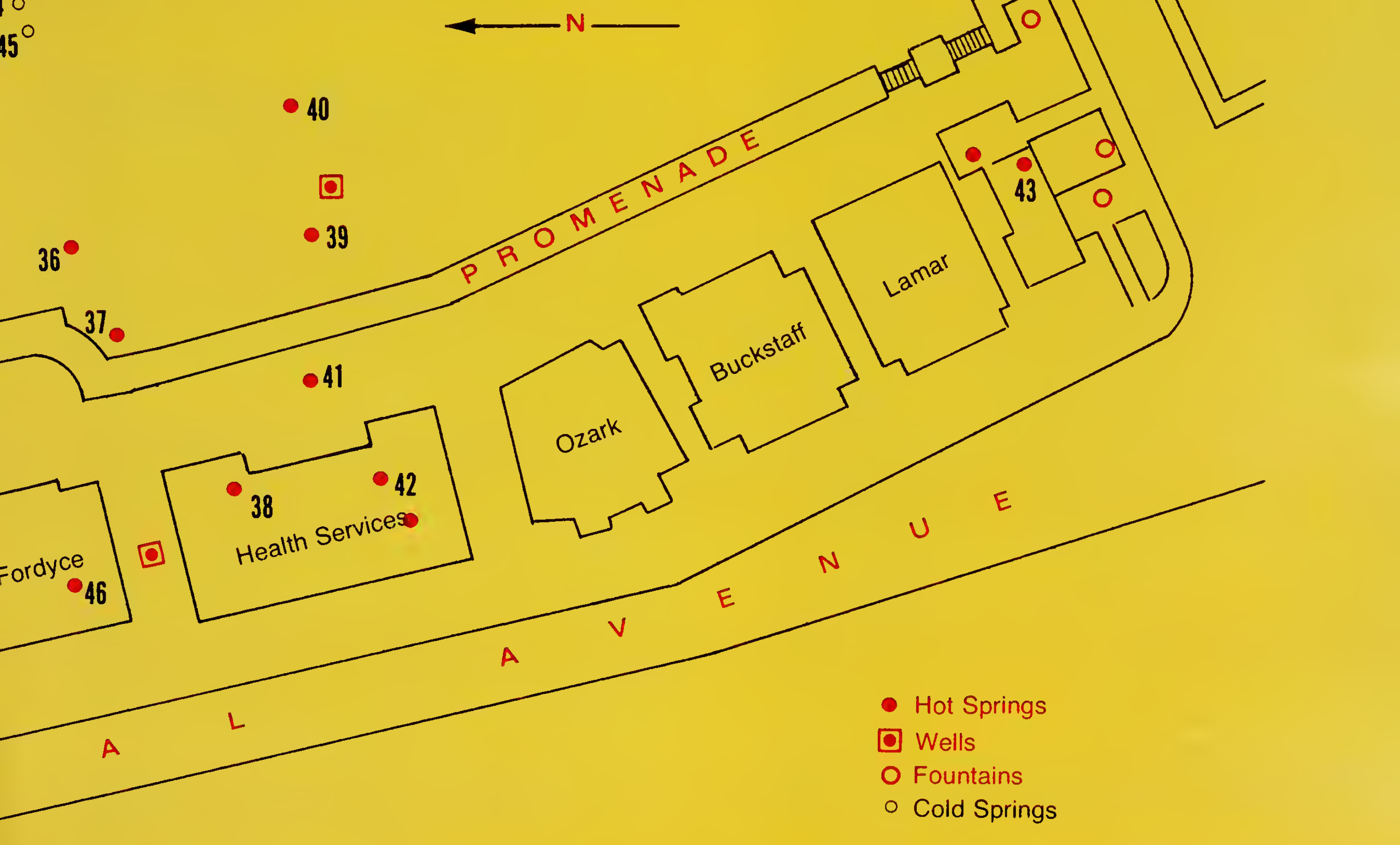


Thermal Springs in the Contiguous States

The Novaculite is brittle, and some of it is also quite porous. It was similarly fractured during folding and uplift.

Rainwater falling into the valley first percolates down through a shallow and rocky soil cover. Here, it picks up carbon dioxide gas given off by organisms living in the soil. The carbon dioxide dissolves in water, forming carbonic acid. As the rainwater continues to percolate downward through the Bigfork Chert and Arkansas Novaculite, the carbonic acid causes the water to dissolve grains of calcium

1 Egg
2 Arsenic
3 Arlington
4 Cliff
5 Avenue
6 Boiler House
7 Imperial (N)
8 Crystal
9 Rector
10 Cave
11 Little Iron (N)
12 Little Geyser
13 Little Iron (S)
14 Ral
15 Big Iron
16 Imperial (S)
17 Arsenic (N)
18 Hitchcock
19 Sumpter
20 Superior (N)
21 Alum
22 Superior (S)
23 Twin (N)
24 Twin (S)
25 Old Hale
26 Palace
27 Tunnel
28 Maurice
29 Dripping
30 Arch
31 Haywood
32 John W. Noble
33 Lamar
34 H. W. Wiley
35 Ed Hardin
36 Eisele
37 Stevens
38 Horse Shoe
39 Army & Navy
40 W.J. Little
41 Mud
42 Magnesia
43 Reservoir
44 Liver (cold)
45 Kidney (cold)
46 Fordyce



DISTRIBUTION of the SPRINGS

carbonate scattered throughout the rock. The rainwater is thus gradually transformed into a mildly alkaline, pleasant tasting solution. The journey downward is slow, a little over a foot (30 centimeters) per year. As the water becomes heated at depth, it also dissolves silica from the surrounding rocks. The amount of silica present in the water provides geochemists with an accurate indication of the maximum temperature to which the waters are heated.

Waters collected throughout the broad expanse of the valley slowly converge at a maximum depth of probably between 6000 to 8000 feet (1800 to 2400 meters) to a point possibly just northwest of the hot springs. Here, the rocks are cut by a series of large faults. Cracks and fractures associated with these faults provide the hot water with a ready escape route up to the surface. The trip up is so rapid, that there is very little cooling of the water. Of the approximately four thousand years it takes the rain water to make its round trip, perhaps only a year or so at the very most is needed to get back up to the surface.

As the hot waters approach the surface, there is a small amount of mixing with cooler, surface waters. The presence of small traces of **tritium**, an isotope of hydrogen produced by natural processes in the upper atmosphere and by above-ground testing of thermonuclear bombs, indicates that some of the spring waters contain minor amounts of surface water less than 20 years old. This is not surprising because rainwater can readily soak into the porous tufa and underlying soil. The hot waters seep up through a broad fracture zone that strikes northeast across the face of Hot Springs Mountain. Old tufa masses indicate that at one time some of the spring waters discharged higher up on the hillside than they do today. Within historic times, some of the spring channels have ceased to flow while others have seen a surge of activity. Some of the changes are the results of man's activity. When a well was drilled for the Fordyce Bathhouse, one of the springs, formerly a trickle, leaped to life, while another which flowed vigorously, nearly dried up. Episodes such as this provide credence to the argument that the springs are interconnected. The upper springs, in fact, are in delicate balance with those at lower levels. Increased flow from the lower springs usually results in decreased flow above.

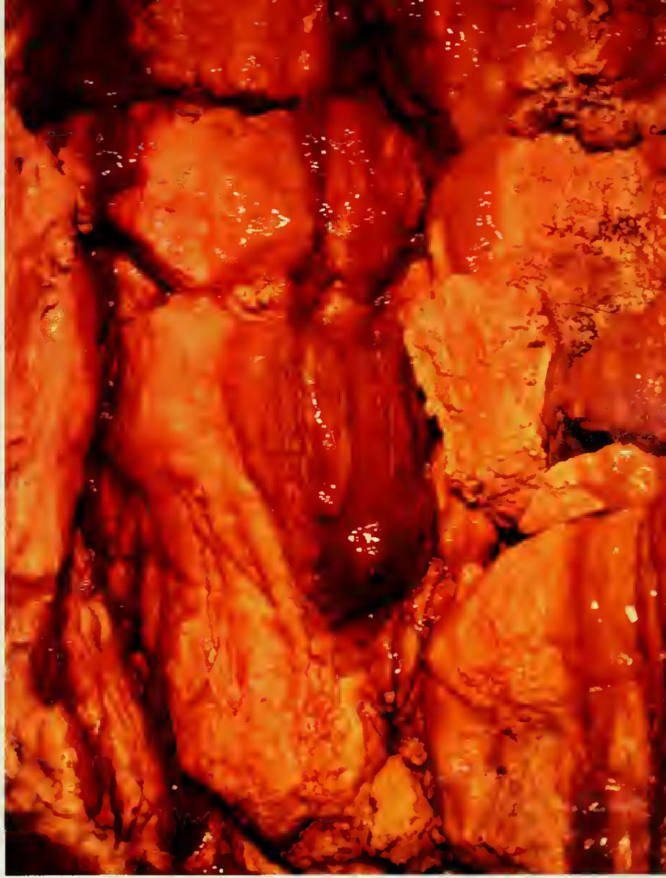
When rising hot waters in uncovered springs come in contact with the atmosphere, they lose some of the dissolved carbon dioxide they picked up on their trip down. As this gas effervesces out of solution, some of the calcium carbonate that is dissolved at depth precipitates out. The crystals of calcium carbonate are very tiny and give the tufa an earthy appearance. It is interesting to realize that precipitation results from loss of gas, not from cooling of the water. Calcium carbonate is one of those odd substances that is actually more soluble in cold water than hot. Trace amounts of dissolved iron in the water oxidize, giving some of the tufa an orange or reddish color.

There appear to be three factors that cause flow of the hot waters to the surface. First, much of the recharge area in the valley to the north is at a slightly higher elevation than the springs. Even though the water descends to great

depth, it emerges at a lower elevation than it went in. Second, heating at depth causes the water to become buoyant. Finally, the distribution of fractured and folded rock is such that large amounts of rainwater are collected from a broad area and then funneled rapidly up through a much narrower escape route.

We still do not know the exact source of heat in our system. The normal increase in temperature with depth in the earth's crust appears to be a sufficient source of heat for the system. This does not rule out the possibility that some other heat source could be involved, although this appears unlikely. The most recent igneous activity in Arkansas occurred some 90 to 100 million years ago. Although it is possible that one of these masses of igneous rock lies burried at depth beneath the Hot Springs area, any molten material would have cooled long ago and would not now be a likely source of heat.

Thermal springs occur elsewhere in the United States, particularly where there has been recent volcanic activity. Hot springs, however, are rare in the central part of the continent. An unusual set of geological conditions has created and maintained the flow of hot waters here in a small valley in central Arkansas. As we will see in the next section, the hot springs are a very recent event in the long geological history of the Ouachita Mountains. How long they will continue to flow is unknown. Management of this resource seeks to insure that the activities of man do not reduce the flow of these waters or alter their chemical quality.



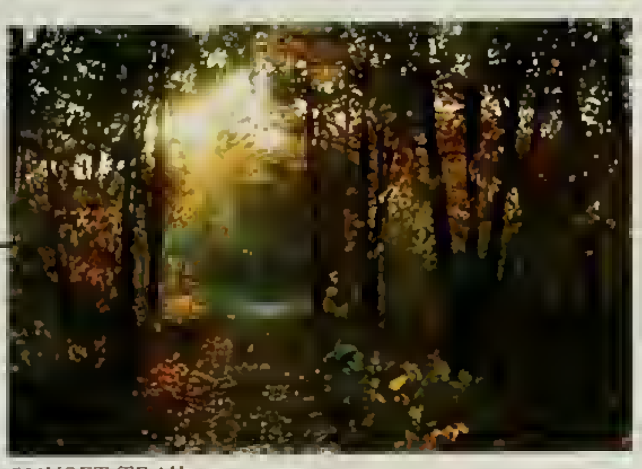
The Tufa as it appears when it is renewed by a continual flow of water.

AN OCEAN WHERE MOUNTAINS NOW STAND

The Ouachita Mountains of central Arkansas and eastern Oklahoma are part of a 1300-mile (2100-kilometer) long belt of folded rocks that extends from eastern Mississippi to western Texas. Most of these rocks are now buried under flat-lying sediments of the Gulf Coastal Plain. Cotton fields, grazing-land, and pine-covered hills conceal most of the eroded remnants of a mountain range that once was of alpine dimensions. A portion of this fold belt is exposed in Hot Springs National Park and surrounding areas in west-central Arkansas. Here, the folded and faulted rocks of the Ouachita Mountains stand as successive chapters in a fascinating, 300 million year old story of the destruction of an ocean basin and the collision of continents.

The history of the Ouachita Mountains really begins over half a billion years ago. The area which is now northern Arkansas was situated on the southern edge of the North American continent, and was covered by a broad, shallow sea. Marine plants and animals which flourished in these warm waters built up calcium carbonate reefs. The region was probably very much like the present-day Bahamas in its appearance.

South of this shallow limestone shelf, the sea floor deepened. The area which is now Hot Springs was part of a great ocean basin which extended east-west, separating the North American continent from the continental masses of South America and Africa several thousand miles (kilometers) to the south. Rivers draining these continental land areas carried sand, silt, and clay into the

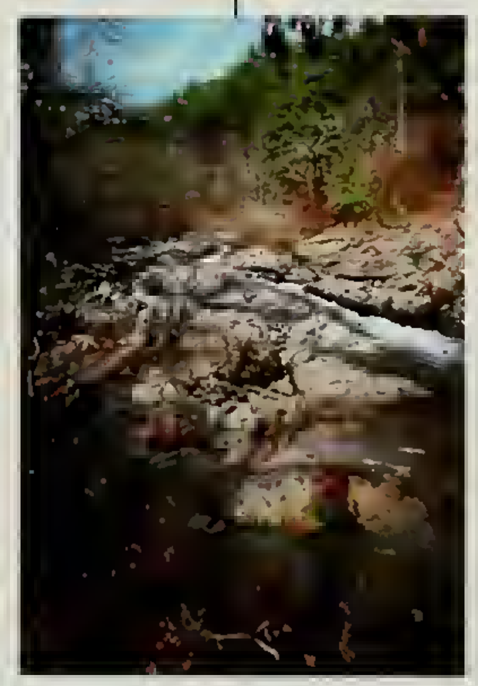


SUNSET TRAIL

BALANCED ROCK

INDIAN QUARRY

MUSIC MOUNTAIN VIEW



GULPHA CREEK

DeSOTO ROCK

GOAT ROCK

Hot Springs National Park

ORIGINAL APPEARANCE OF THE SPRINGS

UNDERGROUND FEATURES

ocean basin, where they slowly accumulated in layers on the sea floor. As these layers of mud and sand were buried by younger layers of sediment, they were squeezed and compacted into the hard beds of shale and sandstone that we see today. Reef plants and animals could not live in the deep waters and muddy bottom of this ocean basin, and the few limestone beds which are found in Ouachita sediments are made up mostly of particles which periodically cascaded down from the shallow carbonate shelf to the north. The open ocean was not without life, however. **Radiolaria,** microscopic one-celled animals, and **graptolites,** small floating colonial animals, lived in the surface waters, feeding on microscopic plants and organic debris. Sponges, worms, and other simple forms of animal life inhabited the sea floor, eating specks of organic matter which settled down slowly through the water column.

Radiolaria and sponges are particularly important characters in the Ouachita story because both types of animals secrete solid, glass-like particles of silica (SiO_2). The remains of these particles now make up much of the sediment we see in the park area. Radiolaria make an elaborate internal support for their protoplasm from silica, and sponges secrete needle-shaped spicules to give their bodies strength and rigidity. When these organisms die, the particles of silica they have made accumulate on the sea floor. If these particles of silica are not diluted by large amounts of clay and sand, they will recrystallize during burial forming an interlocking mass of microscopic crystals of quartz. The soft siliceous mud is thus transformed into a hard, dense rock known as **chert**. Chert is a common type of sedimentary rock in the Ouachitas, and the Bigfork Chert and the Arkansas Novaculite are thick accumulations of chert that make up a large part of the Park area.

Although life was common and wide-spread in the Ouachita sea, the remains of organisms are not well preserved. Fossils are thus uncommon in the Park area. Small transluscent needles and spheres, less than a millimeter in size and representing the remains of sponges and radiolaria, can occasionally be found in the Arkansas Novaculite. Most of the recognizable remains of these organisms, however, have been destroyed by recrystallization. Graptolites have been found in Polk Creek Shale in the Park area, and the feeding trails and burrows of ancient worms are sometimes found exposed on rock surfaces.

Approximately 500 million years ago, forces were set into motion that would eventually destroy the Ouachita ocean basin. In response to stresses deep within the earth, the South American and African continents began to move slowly northward toward North America. As these immense plates of continental crust and lithosphere moved, they slid up and over what had once been ocean crust and seafloor. This movement produced earthquakes, volcanoes, and uplift along the northern edge of South America and Africa, far to the south of what is now Arkansas. Rivers and streams carried eroded particles from these uplifted rocks into the Ouachita basin, where they were deposited as flat-lying muds and sands. The northward movement of South America and Africa was always slow, never exceeding a few inches (centimeters) a year. For reasons unknown, movement at times slowed and apparently even stopped. During these quiet times, the supply of mud and sand from both the north and south dwindled. Sponges and radiolaria, however, continued to flourish. The remains of these animals, undiluted by eroded continental debris, accumulated to form thick beds of chert. The alternating beds of shales, sandstones, and chert that we find in the Park area and which we will describe next thus represent a permanent record of alternating active and quiet times in the destruction of the Ouachita ocean.

ABOUT THE ROCKS

The oldest sediments now exposed in the Ouachita Mountains of Arkansas are a 10,000-foot (3000-meter) thick sequence of shales and sandstones, with minor amounts of limestone and chert, which were deposited between 450 and 500 million years ago. Geologists divide these sediments up by age into a series of separate units or formations. The names given to these formations, the Collier Shale (oldest), Crystal Mountain Sandstone, Mazarn Shale, Blakely Sandstone, and Womble Shale, represent the town or geographic location where the unit was first studied in detail and the major type of sediment present in the unit. These very ancient sediments underlie all of the Hot Springs area at great depth and are not exposed in the Park. There are excellent exposures, however, north and west of the Park, particularly along the shores of Lake Ouachita. The sediments deposited during these early times reflect the first stages of the closing of the Ouachita ocean, a time when there was active movement and an abundant supply of sand, silt, and clay.

The oldest sediment actually exposed in the Park area is the Bigfork Chert, which was deposited on top of the Womble Shale. The alternating beds of recrystallized sponge spicules and radiolaria and shale that make up the Bigfork represent a time of quiescence, when the supply of continental debris was small and sporadic. This brittle rock

Bigfork Chert

was highly fractured and tightly folded during later mountain building. It is found in the valley in the northern part of the city of Hot Springs and serves as the principal recharge area for the thermal springs. Some of the broken pieces of this chert display a peacock irridescence from complex iron phosphate minerals which have been deposited on their fractured surfaces.

The Polk Creek Shale and Missouri Mountain Shale, the next youngest sediments in the Park, signal an increase in the influx of clay into the basin and probably represent an increased intensity in the closing of the ocean basin. The two formations can be distinguished in the Hot Springs area by their color. The Polk Creek is black to grey, and the Missouri Mountain is greenish black, tan, or red. The Polk Creek contains scattered graptolites. Both formations are exposed on the West Mountain Drive at the first outcrops encountered when travelling south from Whittington Avenue. The Blaylock Sandstone, which occurs as a thick layer between the Polk Creek and Missouri Mountain elsewhere in the Ouachitas, is present only as a thin bed in the Park.

About 420 million years ago, the closing of the ocean basin apparently stopped. The reasons for this are not known, but there followed an 80 million year long period of remarkable quiet and stability in the Ouachita region. As in the time of the Bigfork Chert, little sand or clay found its way into the ocean basin. Siliceous animal debris slowly accumulated and was gradually transformed into a remarkably pure, 250-foot (76 meter) thick layer of chert, the lower Arkansas Novaculite. The lower Novaculite is the basis of two of the oldest industries in Arkansas; the making of stone tools and the production of whetstones.

Dunbar and Hunter noted the stone in 1804 as they traveled westward up the Ouachita River in their quest for the hot springs. They make frequent reference to the material in their journals, and Hunter collected samples to take back to New Orleans. Schoolcraft in 1819 gave the Novaculite its present name from the Latin word meaning razor or sharp knife: "A quarry of this mineral (novaculite), three miles above the Hot Springs of the Washitaw, has often been noticed by travelers for its extent and excellency of its quality... Oilstones, for the purpose of honing knives, razors, and carpenter's tools, are occasionally procured from this place, and considerable quantities have been lately taken to New Orleans. It gives a fine edge, and is considered equal to the Turkish Oilstone." Mining and transporting the stone at this early date must have been an arduous task. Today, 'Arkansas Stone' is synonymous throughout this country with natural whetstones.

We do not know what the Indians called the Arkansas Novaculite. They recognized its useful properties, however, and prehistoric quarries on Indian Mountain and Sugarloaf Mountain within the Park area, attest to a long lived and once thriving economic trade based on the making of stone knives and projectile points.

What properties of novaculite allow it to be made both into a knife and a sharpening stone? Actually, novaculite varies greatly in texture, color, and hardness. The Indian quarrymen sought out hard, dense, finely grained material that produced a glass-like scalloped fracture and sharp edges when broken or chipped. Most Whetstones, on the other hand, are made from novaculite that is less dense and contains numerous tiny pores. The ridges of hard silica between these pores give the surface of the stone a good

biting surface, which can sharpen a steel blade quickly. The abundance of pores varies, and whetstones are graded from coarse, with many pores (soft Washita stone), to extra-fine (Black Hard Arkansas stone). The Indians mined mostly Hard Arkansas, a white, dense stone. Because of its scarcity, only a small quantity of Black Hard Arkansas was used for tools and projectile points. The pores have resulted from solution of tiny grains of carbonate. Some parts of the Upper Novaculite which contained abundant carbonate have been leached so extensively, only a fine powder, known as **Tripoli,** remains.

Those porous varieties of novaculite known as Washita Stone show colorful banding and mottling which results from the precipitation of iron and manganese minerals from solutions which have percolated through the rock during weathering.

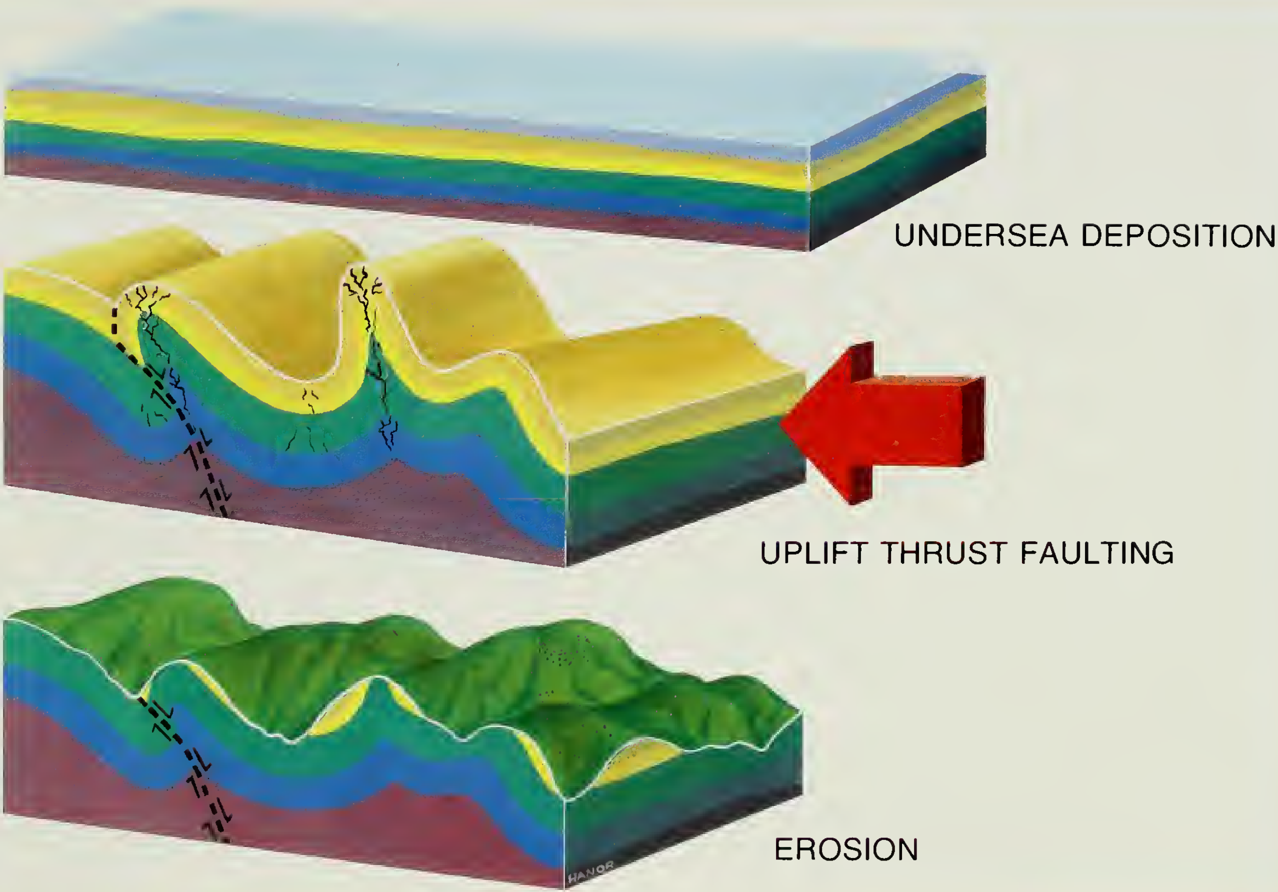
There are some shale layers and conglomerate in the lower novaculite. A thin, bright red layer, resembling Catlinite, the Indian Pipestone, occurs in places on Sugarloaf Mountain. The middle portion of the Arkansas Novaculite is made up mostly of grey shale and thin, black chert. The upper portion consists of alternating shale and chert. The Novaculite is exposed along all the taller ridges in the Park area.

The time of deposition of the Arkansas Novaculite was a time of general crustal stability: an interval of relative calm before the final episode of crustal upheaval that would end in the eventual destruction of the Ouachita ocean and the creation of the Ouachita mountain range.

Colorful Novaculite

COLLISION OF CONTINENTS

The calm was broken by the rapid influx of sand and clay into the basin and by the eruption of volcanoes in the south. Masses of quartz sand cascaded off the shelf to the north and accumulated in a large lobe on the sea floor 400 feet (120 meters) thick and 30 miles (50 kilometers) across. This formation is known as the Hot Springs Sandstone and is well exposed in Gulpha Gorge and at the City water works. Clays and sands were carried into the basin at increasing rates. The ocean basin may have been about 500 miles (800 kilometers) wide at this time, and as South America once again began to move northward, the basin rapidly narrowed and deepened. A tremendous mass of clays and sand over 14,000 feet (4300 meters) thick were deposited in a 40 million year period of time. The Stanley Shale, which makes up the lower part of this sequence, is the youngest Ouachita sediment exposed in the Park. It can be seen in the stream bed in the south part of Gulpha Gorge, and underlies all of the broad Ouachita River valley south of the city of Hot Springs. There are magnificent exposures of the overlying Jackfork shales and sandstones at DeGray


UNDERSEA DEPOSITION
UPLIFT THRUST FAULTING
EROSION
HANOR

Dam, 30 miles (50 kilometers) south of Hot Springs.

By about 320 million years ago, the ocean basin finally closed and collision of the North and South American continents began. Sediments which had been deposited in the Ouachita basin were shoved up against the North American continent. Great faults or breaks occurred, and huge, sheet-like blocks of crumpled sediment were thrust forward on top of one another, much as though a giant pavement had been broken into slabs and the pieces shoved into an immense lop-sided pile.

The zone of folding and faulting migrated northward as the continents pressed and ground together. A narrow, deep trough formed along the present Arkansas River Valley and 20,000 feet (6000 meters) of sands and shales of the Atoka Formation were deposited and then almost immediately deformed as mountain building continued.

By the end of mid-Pennsylvanian time, about 300 million years ago, continental collision slowed, then ceased. The sediments of the Ouachitas had been welded on, to become a permanent part of the North American continent. Waters trapped in the sediments and between the thrust sheets during collision percolated slowly upward through the mass of slowly deforming rock. As these warm waters rose and cooled, they deposited dissolved silica as quartz crystals along open fractures in the crumpled sediment. Many small quartz veins cut across rocks in the Park area. In other parts of the Ouachitas, where the fractures were more open and there was a greater flow of water, spectacular clusters and crusts of quartz crystals formed, for which Arkansas has long been famous.

Our story of the North and South American continents does not quite end here. Soon after deformation of the Ouachitas had been completed, forces deep within the earth reversed, and the continents began to drift slowly apart. A new ocean basin was formed: the Gulf of Mexico. At various times during this separation, masses of hot, molten magma intruded their way up from great depth within the earth through the Ouachita fold belt. Several of these large intrusions, including Magnet Cove, now lie between Hot Springs and Little Rock. A few small, vein-like igneous intrusions called **dikes** are found in the Park area. Most of these have been highly weathered and are now difficult to locate.

As separation of the North and South American continents continued, eroded debris from the uplifted Ouachitas was deposited in the newly-formed ocean basin, helping to create the present Gulf Coastal Plain. Much of the Ouachita fold belt slowly sank and was buried under great thicknesses of younger, flat-lying sediment. In a few places, such as Hot Springs National Park and the surrounding region, we are fortunate enough to be able to see portions of this great mountain range which have escaped burial.


Tilted Novaculite Beds with Cross Jointing.

BACK TO THE SEA

There is abundant evidence in the Park of the magnitude of the forces which created the Ouachita Mountains. From atop the overlooks on North and West Mountains the visitor can see a series of ridges to the north and east. These mark the continuation of the sinuous trace of the Zig-Zag Mountains, remnants of giant folds produced during mountain building. Tilted and overturned beds of Ouachita sediments are exposed in many places on the hillside west of Central Avenue and in Gulpha Gorge. Even the massive Lower Novaculite was bent under the great pressures which accompanied deformation. The Bigfork Chert, with its alternating layers of chert and shale, shows highly contorted and complicated folds. It is sometimes hard to believe that these sediments were originally deposited on a nearly flat seafloor.

While the stresses were great, the rock bent and then broke. Small fractures, or **joints**, occur where the rock has been broken but not offset. There is a good exposure of Arkansas Novaculite on the top of West Mountain that shows the tilted beds of chert with numerous joints set at right angles to bedding.

A **fault** is a break in the rocks where one side has moved up or down or laterally relative to the other. There is a major fault on the south face of Sugarloaf Mountain

where the block of crust south of the break has dropped down about 500 feet (150 meters) relative to the block on the north. A pronounced change in vegetation, which runs the length of the mountain, marks the trace of this fault. Faults also cut Hot Springs Mountain and appear to influence the distribution of the thermal springs. A small fault traverses Gulpha Gorge. One of the small faults in the western part of the Park contains abundant pyrite (iron sulfide). Part of this deposit was even mined. Prospectors for the most part have been disappointed, however, and metal production in the Ouachitas has been limited.

As spectacular in their way as the forces that created the Ouachitas, are the natural forces presently at work destroying them. Even as mountain building was progressing, uplifted sediments of the Ouachitas were being attacked by rain and running water. Material was carried off by rivers and streams to be deposited elsewhere.

Different rock units respond differently to the forces of weathering and erosion. Shales, like those in the Stanley formation, are relatively soft and easily eroded. The Stanley now underlies most of the broad valley of the Ouachita River south of the City of Hot Springs. The Novaculite and Hot Springs Sandstone, on the other hand, are hard and more resistant to erosion. These sediments now form the ridges that trace the sinuosities and offsets of Ouachita folding and faulting. Even these units, however, are susceptible to weathering. Novaculite, for example, once extended in a broad arch between West Mountain and Sugarloaf Mountain. The material between these two ridges has been eroded away, exposing the underlying Bigfork Chert, which forms the valley floor.

Vegetation plays an important role in the erosion of the Novaculite ridges. As trees grow on the hillsides, their roots penetrate through the thin soil into joints and cracks in the rock. When a tree dies and topples over with its roots intact, the rock is broken up into angular blocks and cobbles. During torrential rain, these rock fragments move downhill, forming a mass of debris known as **talus**. Good examples of these processes at work can be found on the east side of Hot Springs Mountain, above Gulpha Gorge. In some areas, plants cannot grow because of movement of the talus. Broad, desolate areas covered with angular blocks and devoid of vegetation result. Some of the more spectacular examples of these areas in the vicinity of the Park have been given equally spectacular names: Blowout Mountain and Hell's Half Acre.

Some of the most resistant portions of the Novaculite have been etched and shaped into massive pinnacles, which stand as sentinels to the valleys below. Goat Rock on Hot Springs Mountain and Balanced Rock on Sugarloaf Mountain are the two most impressive of these monoliths. Erosion is taking place along the stream beds as well. Potholes are found in the lower reaches of Gulpha Gorge, where stream waters have swirled cobbles around in depressions in the Stanley Shale.

Erosion is a slow, but relentless process. It has been going on in the Ouachitas for the last 300 million years and will continue as long as there are hills still standing.

NOVACULITE OUTCROP
ON SUGAR LOAF MOUNTAIN

LIFE ON THE
NOVACULITE

GEOLOGY AND MAN

Compared to the vast extent of geologic time, man's presence in the Valley of the Hot Springs has been brief. Although civilization has succeeded in bringing considerable change to the landscape, geology continues to influence the activities of visitor and resident alike.

The hot waters have always been the focal point of the area. Armed with a copy of **Cutter's Guide,** the visitor of a hundred years ago disembarked at the Iron Mountain railroad station to begin a leisurely and extended program of therapeutic bathing and resort activity. The modern visitor to the Park, who is more likely to arrive by car and have less available time, also comes attracted by the curious existence of hot water flowing from the ground. The golden age of resort therapy, however, has passed, and many of the fine hotels which once stood at the nearby areas of Potash Sulfur Springs and White Sulfur Springs exist no more. While the social climate has changed, and people are generally less familiar with the relaxing therapy of the baths, there continues to be an enduring interest in the baths and the buildings along Bathhouse Row.

Almost every visitor chooses to taste the hot water. It is refreshing to find and to drink a water not treated with chemicals and which is devoid of contaminants, bacteria, or

As they quarried, did the Indians preserve the Balanced Rock or create it for some lasting purpose?

Carried to the springs to relieve dropsy, an Indian recovered to walk away. Coming from great distances, fever-racked plantation owners relied on Indian guides.

viruses. Each year, great quantities of this water are carried off in jugs and bottles from the fountains in the Park. The cold water springs in the Park and surrounding area are also of exceptional quality, and waters from the Three Sisters Springs in the Ouachita State Park and Mountain Valley continue to have large numbers of adherents. Each of the waters in the region is deemed to have a distinctive, pleasant taste. A visit to Hot Springs definitely inspires a new appreciation for this natural resource.

Geology has dictated the location of both the Park and the city of Hot Springs. The mountain ridges are fairly inaccessible, and most of the residential development has been in the more gently rolling terrain toward the south. The fact that mountain tops are not suitable for housing has enabled the Park to acquire more of these lands for recreational use and to protect the integrity of the recharge

Carriage Entrance. The stonework comprised a gateway and other features of a grand design.

Formal Entrance. Time has recorded the changed use and appearance of the middle of Bathhouse Row. The entrance pylons endure.

Maurice Historic Spring. This structure, the original display spring, once was prominent, then hidden, and is now slated to reappear.

area for the hot springs. The ridges of the Zig Zag Mountains are ideal for trails, and their crests offer long, gently undulating paths. The sides are steeper, but offer a wide variety of plant life, glimpses of fur and feathers, and the sounds of action in the forest.

The trails and roads that wind their way through the hills have been developed with foresight and are designed to serve the long-range needs of man and to provide enjoyment for many generations. An example is the gently curving road on Hot Springs Mountain, which was built in 1884 to accomodate horse-drawn vehicles. Very few changes were needed to serve modern auto traffic. On the other hand, the distribution of the hills compounds traffic problems within the city of Hot Springs. A by-pass through the heart of the city, however, is not feasible. First, it would disrupt the springs. Second, undercutting of the slopes of the mountains would lead to further disaster: rockslides and slumping.

The visitor to the Park who heads up any one of a number of the many fine trails that trace their way through

the area will discover areas of novaculite that show evidence of previous quarrying activity. The workings near Quarry Street, on North Mountain, were in operation until 1875, when all quarrying within the Hot Springs Reservation was prohibited. The Park has recently acquired a tract on Indian Mountain which was quarried for whetstone material by the Pike Company, later by the Norton Company.The whetstone quarry, like many others in the region, was originally the site of Indian workings. The largest undisturbed Indian quarry is also located on Indian Mountain. It has been protected from commercial development because of the continuing interest of the Fordyce family in local Indian history and culture. The remarkable foresight of this family in preserving the quarry has been matched by their generosity in donating these lands to the Park. The visitor who journeys up the hillside to this site will likely follow trails once used by Indian men and women to carry stone and supplies. The trail from Gulpha Gorge up Hot Springs Mountain to Goat Rock takes the hiker past massive, overturned beds of Hot Springs Sandstone and Arkansas Novaculite. It is possible to tell that they are overturned, because the older Novaculite now lies on top of the younger sandstone! Talus covered slopes attest to the continued erosion of these mountains.

In the bathhouse area, geologic features of interest include the display hot springs, remnants of tufa, and exposures of Hot Springs Sandstone cut by Quartz veins. There is also a wide variety of exotic geological materials that

Marble and Bronze Thermal Water Drinking Fountain.

A network of trails invites companionship with friends and nature.

have been imported into the Park area for decorative purposes. We tend to take such things for granted and may not even recognize them as natural materials. Many of them, however, are interesting in their own right. The Noble Fountain is constructed of marble, as are parts of many of the bathhouses. The Balustrade and entrance pylons to the Park are chipped and turned from limestone, a rock common in many parts of the world, but rare in the Ouachitas. Unfortunately, acids from auto traffic are exacting a toll on these distinctive structures, and they are steadily deteriorating. Red granite, a more durable stone, is represented by the old U.S. Reservation marker on the trail which leads from Reserve Street (formerly Reservation Street) to the Park campground. Near the Visitor Center, the curb of Reserve Street is lined with hand-hewn stone — a rare commodity today. Many of the old retaining walls along roads, trails, and building sites are buttressed with rock, most of it native in origin. The historic Maurice Spring is walled with an attractive combination of native tufa and limestone from Batesville. The platform to this structure, however, is of a man-made stone; concrete. It is really a reservoir that encloses a tan-colored cone of tufa still in the process of being formed by the springs within.

A visit to the Park can be concluded with a drive or hike to the overlooks on North and West mountains. These afford a panoramic overview of the Ouachitas and the Valley of the Hot Springs. Here, in a moment of quiet contemplation, one can truly sense the power and majesty of geologic events which have shaped this part of the earth's crust.

Author

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Illustrator

Bert Hanor applies art techniques easily — the product of 30 years of experience with a large city agency. For the last 10 years the options of retirement and an irrepressible urge to create has led him to engage in challenging projects. His capability is recognized by abundant awards, which he accepts with modesty.